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Digital Value Chain Smart Additive Manufacturing: Pillars and Principals

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Abstract

This research investigates the implications of smart additive manufacturing (SAM), which is also known as smart three-dimensional (3D) printing, for industrial production logistics and inventory management as well as for digital supply chains (DSCs) and digital value chains (DVCs). The research is conducted within the context of Industry 4.0. The fourth industrial revolution is frequently referred to as "Industry 4.0." This transformation has given rise to the development of new digital technologies as well as an increase in the degree to which the production environment is digitized and automated. If organizations want to continue to be competitive in the market, they need to implement manufacturing technologies that support machine-to-machine and human-to-machine communication in a virtual environment. These technologies are called "intelligent factories." The inclusion of advanced digitalization, such as the Internet and intelligent things (machines and products), enables the linking of all aspects associated to production processes. This may be accomplished through the use of intelligent things (machines and commodities).

Introduction

This is made feasible by digital technologies like as artificial intelligence (AI) and SAM, which are examples of advanced digitization. These technologies are examples of what is known as advanced digitization. Various other names for it include the "digital factory," "smart factory," "smart manufacturing," "smart firm," "industrial internet," and "integrated industry." This is due to the fact that the link between the real world and the digital factory generates what is referred to as a "cyber physical system." As a result of the development of Industry 4.0, manufacturing that is digitally enabled has been the focus of a significant amount of attention. Because of this, it is now feasible to create items at a quicker pace and with a higher degree of customization than was before conceivable. Because of this, the development of novel digital technologies and unorthodox business models is hastening an industry transition that has an impact on both the traditional means of doing business and the organizational framework of the market. This transition has an effect on both the conventional methods of conducting business and the organizational framework of the market.This new digital industrial paradigm is also having a considerable impact on the digitalization of production logistics applications, inventory management, supply chains (SCs), and value chains (VCs). These concepts are also referred to as "chains." These are the many chains that are responsible for the production of products and services. As a direct result of this, new terms such as "digital inventory," "digital supply chains" (DSCs), and "digital value chains" (DVCs) have been coined in order to express the fast change that is required by Industry 4.0. These terms have been developed as a direct consequence of this.

Literature Review

Miltenburg 2001, Spicer et al. (2002). In this particular context, the research will concentrate its attention on discrete production systems as the principal subject of its investigation. Assembly lines and production lines are often separate components of the manufacturing system that is used in the automobile industry. This is because assembly lines and production lines serve unique purposes. An assembly line system is a sort of manufacturing technique that refers to the process of assembling a finished product from its component parts and subassemblies in a sequential sequence. This procedure refers to the process of putting together a finished product from its component parts and subassemblies. This procedure can be broken down into a number of distinct subcategories according to a variety of factors, such as the following: the frequency (first time installation and reconfiguration); the level of automation (manual line and automated line); the number of models; the line control (paced line, unpaced asynchronous line, and unpaced synchronous line); the number of models; and the line control. When it comes to the creation of new systems, the industry nearly always chooses symmetric

system designs, and the reason for this choice is because this is the preference of industry professionals.
Rampersad (2011). There is a relationship that can be made between the assembly process and the assembly system that is being used inside an assembly line system. The assembly system is made up of the system layout, the system structure, and the system components, whereas the assembly process is made up of the assembly strategy, the assembly structure, and the assembly operations. The assembly system is responsible, not only for the last step of putting the product's finishing touches on it, but also for the step before that.
According to Heilala and Voho (2011), the optimal manufacturing system in the current dynamic and variable market environment must be constructed to be semi-automatic (that is, automated and manual workstations with automated and manual material handling). Building the ideal manufacturing system is essential in order to develop the ideal manufacturing system, which itself requires building the ideal manufacturing system. In addition to this, Heilala and Voho (2011) argued that in order to build the best production system, the system in question must be at least partially automated. They based their assertion on the fact that in order to develop the best production system, the system in question must be the best. A presentation was given on the design factors that are necessary in order to establish the most effective assembly line system that can possibly be created. advocated the use of walking worker assembly lines, in which each worker would be responsible for assembling the product from the very first workstation all the way to the very last workstation in an effort to maintain and expand the assembly line's flexibility with regard to the amount of product that could be produced. This was done in order to maximize the amount of product that could be produced. This action was taken in order to preserve and expand the available quantity of the product that could be produced.
Buchi et al., (2010). During the process of conducting an analysis of the released information, a number of different phrases, including data-driven production, advanced manufacturing, factories of the future, the fourth industrial revolution, and technologies for Industry 4.0, were used interchangeably. These ideas are applicable to the course that the manufacturing sector will take in the years to come, and it will do so by capitalizing on linked and networked technology to provide value for businesses as well as for society. More specifically, these concepts pertain to the course of action that the industrial sector will take in the future. In a larger sense, the phrase refers to any machine that is outfitted with data-gathering equipment and is able to connect with other machines and systems in order to accomplish a certain set of goals. In other words, the phrase refers to any machine that is intelligent. Recent studies have shown that there has been a considerable surge in interest in smart manufacturing, which focuses an emphasis on integration, interoperability, and the closure of the gap that now exists between the real world and the virtual world.
According to Frank et al. (2019), the goal of smart manufacturing is to make all production processes much more effective by utilizing data gathered throughout the lifespan of a product and storing it in intelligent systems. This may be accomplished by making use of the information collected. The idea of Industry 4.0 may be partitioned into two distinct components: the underlying technology and the front end. Initiatives such as intelligent working, intelligent goods, intelligent supply chains, and intelligent manufacturing are all addressed by the front-end technology component. The Internet of Things (IoT), Big Data and Analytics, as well as Cloud Services, are all fundamental components of the modern-day technological environment. A multi-layered perspective of production settings was presented, with the physical layer consisting of the shop floor and the operations that are visible to the naked eye, the data layer consisting of the uploading of data to the cloud, the intelligence layer consisting of software and tools for analysis, and the control layer consisting of human supervision. In total, there were four layers.

Technology Based Back through

Additive manufacturing, sometimes referred to as AM for short, has been at the forefront of technological breakthroughs almost from the moment they were first introduced. As a consequence of this, AM has been the focal point of research projects that attempt to leverage on AM's strengths and accelerate digital transformation in the manufacturing industry. AM increases the level of digital connection between businesses and their customers. It also enables businesses to quickly print on-site, personalize mass production, and move on to direct manufacturing while at the same time reducing the amount of waste produced, the cost of shipping, and the amount of time it takes to deliver products. AM also raises the level of digital connection between businesses and their customers. In addition to this, it possesses the capability of making SCs easier to understand.In this setting, Smart Asset Management (SAM), which blends AM with intelligent or smart technology, devices, and systems, has come into existence. SAM is an abbreviation for "smart asset management." In light of the haste and growth that have been brought about by Industry 4.0, it is extremely necessary to explore the contributions and advantages, as well as the risks and challenges, that will be brought about when SAM becomes a key part of DSCs and, eventually, in DVCs. This is because Industry 4.0 has brought about a speed and expansion that has brought about these changes.

One of the most intriguing and potentially fruitful study subjects that has been suggested up to this point is the interaction that exists between the developing main enabling technologies of Industry 4.0 (such as SAM) and production logistics and inventory management, as well as DSCs and DVCs. This is one of the most fascinating study topics that has been presented. Because it is difficult to deny the impact that AM technology has had and will continue to have on production logistics and inventory management, SCs and VCs, it is extremely vital to have a fundamental grasp of SAM and the potential ramifications it may have on the manufacturing sector. This is because it is impossible to refute the influence that AM technology has had and will continue to have on production logistics and inventory management, SCs and VCs.

This study provides a critical analysis that analyzes the most current research and advancements that have been done to date on the consequences that SAM has had on the manufacturing industry. The ideas of digital manufacturing, DSCs, and DVCs are discussed in Section 2, which may be found below. After that, you will go on to Section 3, which will explain both smart manufacturing and SAM to you. In the next section, we are going to show and talk about the outcomes of our research. In specifically, we are going to concentrate on the linkages that exist between SAM, production logistics and inventory management, DSCs, and DVCs. In conclusion, Section 5 presents a concise review of the findings that emerged as the most significant from our research.

Digital Value Chains

This research investigates the implications of smart additive manufacturing (SAM), which is also known as smart three-dimensional (3D) printing, for industrial production logistics and inventory management as well as for digital supply chains (DSCs) and digital value chains (DVCs). The research is conducted within the context of Industry 4.0. The fourth industrial revolution is frequently referred to as "Industry 4.0." This transformation has given rise to the development of new digital technologies as well as an increase in the degree to which the production environment is digitized and automated. If organizations want to continue to be competitive in the market, they need to implement manufacturing technologies that support machine-to-machine and human-to-machine communication in a virtual environment. These technologies are called "intelligent factories." The inclusion of advanced digitalization, such as the Internet and intelligent things (machines and products), enables the linking of all aspects associated to production processes. This may be accomplished through the use of intelligent things (machines and commodities). This is made feasible by digital technologies like as artificial intelligence (AI) and SAM, which are examples of advanced digitization. These technologies are examples of what is known as advanced digitization. Various other names for it include the "digital factory," "smart factory," "smart manufacturing," "smart firm," "industrial internet," and "integrated industry." This is due to the fact that the link between the real world and the digital factory generates what is referred to as a "cyber physical system." As a result of the development of Industry 4.0, manufacturing that is digitally enabled has been the focus of a significant amount of attention.

Because of this, it is now feasible to create items at a quicker pace and with a higher degree of customization than was before conceivable. Because of this, the development of novel digital technologies and unorthodox business models is hastening an industry transition that has an impact on both the traditional means of doing business and the organizational framework of the market. This transition has an effect on both the conventional methods of conducting business and the organizational framework of the market.This new digital industrial paradigm is also having a considerable impact on the digitalization of production logistics applications, inventory management, supply chains (SCs), and value chains (VCs). These concepts are also referred to as "chains." These are the many chains that are responsible for the production of products and services. As a direct result of this, new terms such as "digital inventory," "digital supply chains" (DSCs), and "digital value chains" (DVCs) have been coined in order to express the fast change that is required by Industry 4.0. These terms have been developed as a direct consequence of this.

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SAM Critical Analysis

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The use of augmented reality can boost the fabrication speed in a SAM process by easing the transfer of layout information between a reconfigurable additive manufacturing (AM) system made up of robotic arms and its corresponding digital twin for toolpath planning and simulation. This can be accomplished by augmenting the real-world environment with virtual elements. Because of this, it is possible to implement numerous independent actuators for simultaneous material deposition without running the danger of the actuators colliding with one another.

Augmented reality (AR) can support the detection of problems in an AM process that are caused by inaccessible measurements or parts movements that are difficult to anticipate. This can be accomplished by using an AR-based application that enables the evaluation of individually engineered parts based on virtual three-dimensional (3D) computer-aided design models (CAD) projected to the intended installation-site. This may be done with the assistance of an application that utilizes AR technology.
When owners of businesses make the decision to employ digital transformation processes, they often have various goals in mind at the time of making that decision. On the other hand, decreasing the amount of time required to bring a product or service to market is likely to be one of the goals that is both the most evident and the most vital. After all, time is the resource that holds the most value for them right now as well as in the future, regardless of the setting. As a consequence of this, a sizeable advantage may be accomplished by introducing ideas to the market in a more expedient manner than the other businesses in the industry.

Development and Use of Digital Manufacturing Techniques

The development and use of digital manufacturing technologies are to blame for the paradigm shift that has taken place in the industry; furthermore, the simplicity with which these technologies may be implemented has had a considerable impact on the degree to which the sector is able to compete with other businesses in the same field. Both the internal dynamics of an organization and the external environment in which it operates may have an effect on the speed and efficiency with which new technologies may be incorporated. On the other hand, the influence may be lessened if the organization in question have sufficient technological capabilities as well as an advanced degree of maturity. Additionally, the implementation of these digital technologies has the potential to have a significant impact on the performance of an organization (in particular, its flexibility, design, delivery, and overall quality). This impact may be positive or negative, depending on the circumstances.
In light of this, the concept of digital transformation has evolved over the course of the previous several years as a particularly contested subject in academic debate. This topic is frequently connected to the fourth industrial revolution (Industrie 4.0) and its new industrial paradigm. However, in the quickly changing world of today, competition is no longer only a concern between individual enterprises; rather, it is now also a problem for the supply chains that are engaged in the many transactions. This was true in the past, but not anymore.
According to Lee and Billington, who authored the aforementioned article, "The supply chain is a network of producers and distributors that supply raw materials, convert them into intermediate goods and final products, and distribute final products to customers." "The supply chain" The contribution that SCs and production logistics provide to the expansion of the global economy is of critical significance. Dynamic supply networks are characterized by continuous development as a result of the quick changes that take place in a range of marketplaces as well as in economic, financial, social, and technical aspects. This is because dynamic supply chains are designed to accommodate these types of shifts. For supply chains (and the associated value chains, or VCs) to remain competitive in the industry, they need to go through changes in terms of their size, shape, and configuration, as well as the ways by which they are coordinated, controlled, and managed. These changes are necessary to ensure that supply chains (and the supporting VCs) can continue to be profitable.

Strengths of Technology

Because it strengthens the relationships between players in the supply chain and makes it possible for SCs to be managed more efficiently, digital transformation is an urgent necessity at this juncture. This is what gives rise to DSCs and the DVCs that correspond to them. When distributed system controllers (DSCs) reach a higher level of automation and integration among their systems, the machinery and apparatus used in production are synchronized with one another through the use of the internet and intelligent sensors, and all of the data created during this process is saved to the cloud. This occurs when distributed system controllers (DSCs) reach a higher level of automation and integration among their systems.
However, the strategy for digital transformation needs not only the analysis and selection of the technologies that will be applied, but also the skills, competencies, business models, and

even the organizational structure that must be modified for this transition in order to be successful. To put it another way, it is not just about the technology. In addition, in order for the supply chain to be effective, all of the individuals involved, including managers, employees, and anybody else who is involved in the process, need to adopt not just new methods, but also a new culture.
However, before starting the transformation, it is essential to construct a road map that takes into account the challenges that may be encountered in the future. Before and after a shift to digital operations, a company's management is expected to do a risk assessment of any potential difficulties that may arise. In exchange, digital transformation will make it possible for them to continuously monitor raw materials and assess the supply and availability of the essential machinery. This will allow them to make better business decisions. Because of this, they will be able to make adjustments that are not only effective but also accurate across the entirety of their manufacturing processes.
To summarize, digital transformation need to be regarded as a tactical option for the SCs in which individual firms operate, as well as for the individual companies themselves. Throughout the entirety of the process, organizations, particularly Small and Medium-sized Enterprises (SMEs), are faced with problems on a multitude of fronts, including financial, cultural, legal, technological, and implementation concerns. These challenges may be broken down into many categories. They need to adopt a culture of innovation in addition to a digital transformation plan if they want to be able to continue to be successful in a market that is very competitive. In addition to this, they need to do an analysis and get ready for the inherent challenges and dangers.

Additive Manufacturing, and Smart Additive Manufacturing

Molding, heat treatment, milling, grinding, and other operations are all examples of phases that are necessary in typical manufacturing processes; however, the techniques that make up these stages are not necessarily related to one another in any way. On the other hand, "smart manufacturing" is a process that is technology-driven and makes use of a production system that is entirely integrated and collaborative. This approach was developed in the 1990s. This makes it possible for enterprises to keep an eye on the manufacturing processes and react immediately to any changes that may occur in order to meet the ever-evolving requirements and conditions of factories, SCs, and the expectations of consumers. The notion of smart manufacturing is one that was developed more recently. The industrial machinery used in this system is supplied with intelligent sensors. These sensors are in charge of the data collecting process and are responsible for gathering information on the machine's operating status and performance. After the data have been collected and examined, possibilities to change and improve production performance are searched for.

Conclusions

The phrase "smart manufacturing" refers to a new generation of production systems that make use of cutting-edge technology to monitor and improve the performance of the manufacturing process. These systems are referred to as the "next generation" of production systems. A good illustration of one of these technologies is the use of apparatus that is connected to the internet. An intelligent factory should not only include automation, but also human and machine interaction; the combination of these two factors will result in greater operational efficiency. As it is implemented in a wider variety of devices and networks, the Internet of Things (IoT) may make it possible to achieve higher degrees of automation. Despite this, other technologies, in addition to the Internet of Things, play an important role in the process of smart manufacturing. Artificial intelligence (AI), machine learning, edge computing, predictive analytics, and digital twins are some of the technologies that fall under this category.
Smart manufacturing, which has been lauded as a successful update that enhances resource efficiency and flexibility, was introduced as part of Industry 4.0, which is acknowledged with being successful in its introduction of smart manufacturing. It has become feasible, as a result of the widespread use of the Internet and current engineering technologies, to merge the value-creation processes of consumers and businesses, so making it possible to create an environment that is more amenable to production. This astute technique offers a variety of benefits to

companies, including greater levels of productivity and efficiency, as well as cost savings over the course of the longer term. This is accomplished through optimizing the utilization of labor, energy, and materials in the production of high-quality, individualized products; improving response times to shifts in market demand; and reducing the amount of time it takes for items to be delivered. The increased presence of all of these factors contributes to an increase in the market competitiveness of the organization. In addition, getting rid of production downtime is one of the most effective ways to save costs in terms of increasing productivity, which brings up another important point. The vast majority of modern machinery is fitted with remote sensors and diagnostics that can instantly alert workers to any problems, regardless of where they are located. Because of the application of predictive artificial intelligence technology, it is possible to anticipate prospective problems far in advance of their manifestation and to take preventative actions against them; this, in turn, minimizes the negative effect that these problems have on both the cost and the efficiency of the operation.

Kusiak defines the six pillars that are related with an intelligent industrial atmosphere:

Pillar 1—The development of new manufacturing technologies and processes: AM is one example of a new technology that has inspired the invention of new materials, had an impact on the design and manufacture of products, and opened the door to new application areas. Another example of a new technology is 3D printing, which is another example of a new technology that has had an influence on the design and production of goods.

Pillar 2—Materials: The technique of smart manufacturing allows for the use of any and all types of materials, including those that are based on organic compounds and biomaterials. On the other hand, the emergence of new materials necessitates the development of both new methods of production and the incorporation of these new materials into existing intelligent production systems.

Pillar 3—Data: We are now experiencing a significant increase in the quantity of data acquired from a broad range of sources, some of which have been driven by the adoption of intelligent sensors, wireless technologies, and data analysis. This is something that we have been observing for quite some time. The data will be included into the development of future software applications and programs, as well as into the production of various modeling tools for use in forecasting.

Pillar 4— Engineering that is predictive develops digital models of the phenomena of interest with a high degree of realism, which may subsequently be utilized to influence choices on future production and market conditions.

Pillar 5— The production of products and processes has to be guided by sustainability standards, which should include sustainable product design, sustainable manufacturing techniques, and sustainable materials. This criteria should also be included.

Pillar 6— Sharing of resources and the establishment of new networks: As the manufacturing sector becomes increasingly reliant on digital and virtual technologies, many of the creative and decision-making processes will be required to involve sharing of resources and the establishment of new networks.

Additive Manufacturing

AM stands for additive manufacturing and refers to a "technology that applies the additive-shaping principle and therefore builds physical 3D geometries by successive addition of material." 3D printing is a common term for AM. It was invented in 1986 by Charles Hull, who was also the originator of the stereolithography technique. Since then, it has garnered substantial academic and industry attention due to its capacity to construct intricate structures that can be customized.

According to the published research, additive manufacturing (AM) technology is the driving force behind a paradigm shift in the product development, manufacturing, and distribution processes. For instance, in the year 2010, it was instrumental in the fight against the spread of COVID-19. It did this by supplying custom parts locally and on demand, thereby cutting down on waste and transportation costs. Additionally, it eliminated the requirement for an extensive manufacturing pipeline in the production of face shields, palliative face masks, cotton swabs, hands-free door openers, quarantine booths, and other such items.

AM technology is continuing to transform industries in terms of the technology as well as the materials and processes that are employed, despite the fact that it is no longer a novel concept. AM technology is associated with the following four tenets, according to the European Association of Machine Tool Industries and Related Manufacturing Technologies:

Principle 1— It is much simpler to create new business models that are based on localized production, mass production customisation, and/or the diversification of products and services thanks to the additive manufacturing technology, which may be seen of as a form of innovation.

Principle 2—Performance: Manufacturing components with optimal material distribution, which leads to enhanced performance, is now achievable thanks to additive manufacturing (AM) technology, which makes it possible to build these components.

Principle 3—Sustainability: It is feasible to produce components out of recycled materials or materials that have been utilized in the production process in the past by employing additive manufacturing (AM) technology. As a consequence of this, the technology helps to make it simpler to have a circular economy by lowering the influence that it has on the surrounding environment. When compared to manufacturing processes that depend on traditional technologies, the utilization of this technology leads in the manufacture of goods that are not only less heavy but also more long-lasting. This is because the items are able to better withstand the test of time. In addition to this, it contributes to the reduction of the costs of fuel as well as the pollution that is caused by the activities and industries that are associated with mobility.

Principle 4—Competitiveness: AM technology cuts down on the amount of time it takes to bring a product to market by reducing the amount of time that elapses between the product's conception and its manufacturing. Additionally, AM technology makes it possible for production to be decentralized, which means that the final product can be created in a number of different locations rather than coming from a single factory or plant, which reduces the cost of transportation

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